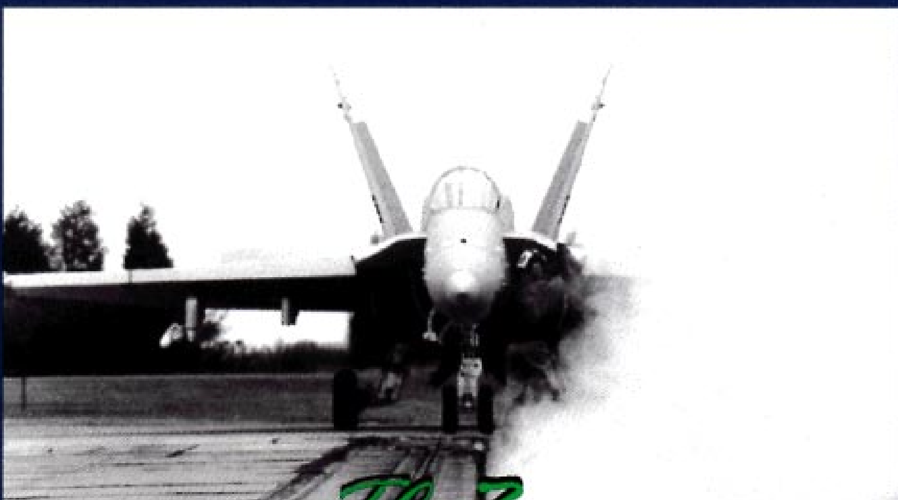
Naval Air Warfare Center Aircraft Division
Patuxent River, MD



TC-7 Steam Catapult and MK-7 Arresting Gear

TC-7 Steam Catapult

Completed in 1954, the TC-7 steam catapult is operated and maintained by the Naval Strike Aircraft Test Squadron at the Naval Air Warfare Center Aircraft Division (NAWCAD), Patuxent River, Maryland. This $6 million underground installation accommodates structural tests and aircraft catapult compatibility studies with all models of carrier aircraft in the U.S. Navy. The site is available to all activities at Patuxent River, as well as fleet activities and foreign aircraft development projects.

The TC-7 catapult was scaled up from a smaller steam catapult built by the British and tested on HMS PERSUS in 1950. Steam catapults are used on all U.S. Navy aircraft carriers. The TC-7 is a linear piston-type steam engine used to launch airplanes up to 85,000 pounds gross weight and is used in USS FORRESTAL class carriers, such as the USS INDEPENDENCE. The TC-7 catapult underwent a $1.6 million modernization project in 1986 and a $200,000 upgrade in 1993, and is considered the Navy's premier aircraft carrier suitability test facility. Since its inauguration in 1954, the TC-7 catapult and arresting gear facility has successfully launched and recovered over 44,000 aircraft.

Prior to the era of steam catapults, the power to launch an aircraft off a carrier was generated by a hydro-pneumatic unit located below the flight deck. The acceleration force was transmitted to the aircraft by flexible, steel-wire cables passing around pulleys; a small trolley running in a track sunk flush in the flight deck was attached to the ends of the cables, and the towing bridle that pulled the aircraft along the deck was hooked to the trolley. With the increased weight of today's aircraft came the need for greater launching speeds, heavier power units, and larger cables and pulleys. It soon became evident that aircraft carriers could not accommodate the massive equipment needed to launch a modern tactical aircraft.

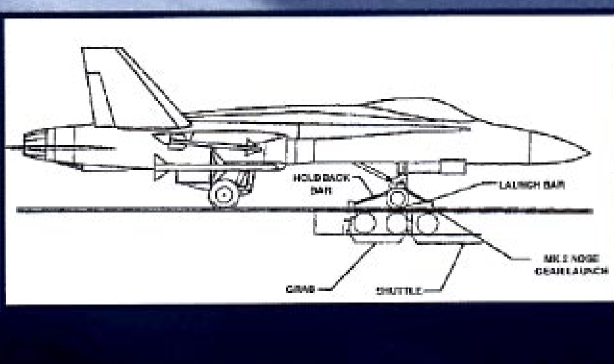
How the Steam Catapult Works

In the steam catapult, a completely different principle is employed in that the shuttle, or trolley, to which the aircraft is connected by its launch bar, is propelled along its track in the deck by two pistons which are directly connected to it, and which slide in two steam cylinders placed side by side under the deck and extending the whole length of the track. Steam pressure acts directly on these pistons and propels them along the cylinders; the comparatively light pistons and the shuttle are the only moving parts of the catapult.

Figure 1 illustrates an aircraft secured by its launch bar to the shuttle and held back against the thrust of its own engines. The nose gear launch equipment is designed to assist in launching aircraft by attaching the nose wheel strut to the towing mechanism of the catapult by way of the aircraft's launch bar. This means of launching aircraft permits a positive and automatic engagement of aircraft to the catapult with fewer personnel than were required by the old bridle system. By eliminating the need for a large number of personnel in close proximity of aircraft during engagement, a greater safety factor is achieved.

The nose gear launching of aircraft also allows for a smooth and rapid operation. The launching sequence is basically the same for all catapults. While an aircraft is waiting for its catapult launch,

Figure 1



it is secured by the launch bar to the shuttle.

A holdback device is connected between the aircraft holdback fitting and the holdback attachment point on the deck. The holdback restrains the aircraft against forward movement prior to actual catapult firing. The capacity selector valve (CSV) system allows for the catapult officer to set the desired energy level of the launch. The catapult officer uses the type of aircraft, aircraft weight, aircraft configuration, wind conditions, and the desired excess aircraft airspeed to find the correct CSV setting from aircraft launching bulletins that are prepared for each type of ship. When the aircraft is ready to be launched with its engines at full power, the launching valves are opened, admitting steam from the receivers to the after side of the main pistons in the power cylinders. The force on the pistons generated by this steam breaks a calibrated weak link in the holdback and accelerates the pistons, shuttle, and aircraft to the required speed along the deck.

At the end of the catapult power stroke, the aircraft automatically disengages from the catapult and continues the launch under its own power. The catapult retraction system can then be actuated to return the catapult shuttle to battery position.

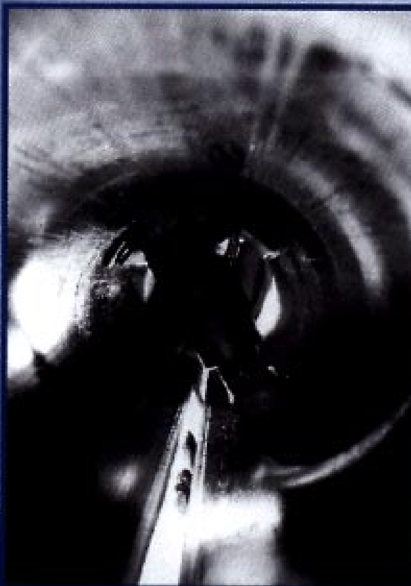
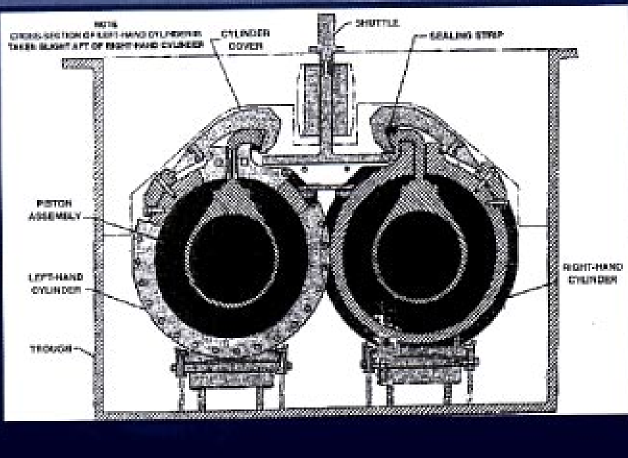


Figure 2 shows a cross-section through the catapult and illustrates how the two power cylinders are installed side by side in the trough formed in the flight deck. This trough is closed by two portable tracks or portions of deck which carry the channel-shaped rails in which the shuttle runs upon its rollers.

The body of the shuttle is in the shape of an inverted "T" of which the upper part projects through a slot between the two channel rails above the deck and forms the hook to which the towing bridle is attached. The flange of the "T" on the underside is furnished at each edge with dogs which engage in corresponding dogs in the driving key attached to the piston. The two pistons and the shuttle are constrained to move axially, but have freedom relative to each other so that slight movement of the track or cylinders is possible. The dogs are provided with ample bearing surfaces. The length of the accelerating stroke, and therefore of the assembled cylinder, is only limited by the length of the ship, but it is necessary to stop the piston assemblies and shuttle when they have reached the end of their available stroke.

Figure 2



At the end of the power stroke, the spear sections of the piston assemblies engage the water brakes. The brake unit consists of two fixed cylinders, or chambers, which are kept full of water using centrifugal action of a vortex induced in each chamber by jets of water. The tapered spear enters the orifice at the chamber's mouth, displacing water aft through the gradually reducing area between the orifice and the entering spear. This action developed high pressure in the brake chambers, which acts on the spears to stop the pistons and the shuttle.

The rotary retraction engine uses hydraulic pressure from the catapult hydraulic system to operate a hydraulic motor and wind mechanism, which feeds the cables on and off the drum to operate the launching shuttle grab. After each shot, the grab is propelled the full length of the launching stroke, where it latches onto the shuttle. The motion is reversed to return the pistons and shuttle to battery position in preparation for the next launch. Although much of the "action" may appear to be going on topside as an aircraft moves from 0 to 160 mph in 2 seconds, you can see that the heart of the operation actually beats underneath the launch area. During test "cat" shots, it's all business, with topside crew and below-deck operators working together as well-oiled as the machinery they support. Aircraft weights and various data are recorded; shuttle, release element, and holdback are set into place; and the valves, pistons, and cylinders that comprise the catapult are prepared for launch. Sound-activated headsets allow for communication between all stations.

MK-7 Arresting Gear Test Site

The MK-7 arresting gear test site is a $3 million underground installation completed in 1961. It is maintained and operated by the Naval Strike Aircraft Test Squadron at NAWCAD Patuxent River, Maryland. The recovery of aircraft on an aircraft carrier flight deck requires equipment designed to shorten aircraft landing runout due to the limited deck space available. This equipment consists of an arresting gear engine reeved with a purchase cable coupled to the deck pendant. The deck pendant is the cable on the carrier flight deck which the aircraft arresting hook engages on landing. The arresting engine is located below the flight deck and absorbs the kinetic energy of the aircraft. Arresting gear currently in use on aircraft carriers in the fleet are the Mark 7 MOD 2 and Mark 7 MOD 3. Structural tests and airplane arresting gear compatibility studies with all models of carrier airplanes in the U.S. Navy are conducted here.

The MK-7 site is used primarily by the squadron, but is available for use by all activities at Patuxent River, as well as other shore and fleet activities. The MK-7 is scaled up from a smaller MK-5 arresting gear. The MK-7 MOD 3 is capable of arresting a 50,000-pound aircraft at 130 knots engaging speed. Due to increased weight and speed of aircraft, larger and heavier arresting gear units were needed to safely stop modern aircraft.

At the MK-7 arresting gear site, operations are equally precise. The arresting gear operates on a hydraulic fluid displacement principle. As a plane approaches the deck, the aircraft's tail hook engages a steel cable, held approximately 3 inches off the deck. Aboard ship, four cables are present to increase the likelihood of an engagement or trap.

How the Arresting Gear Works

An air charge of 400 psi on the accumulator maintains a taut cable system and retracts the cable to battery after an arrestment. The aircraft tail hook engages the cross-deck pendant, which is attached to the purchase cable, reeved around the fixed sheave and the crosshead sheave assemblies. The pendant must be elevated to ensure aircraft hook engagement. A leaf spring supports the deck pendant. The wire supports raise the deck pendant no higher than 5.5 inches above the deck, while allowing the underside of the deck pendant to be no lower than 2 inches above the deck. The purchase cable is the connection between the deck pendant and the arresting engine. The force of an incoming aircraft's forward motion is transmitted from the deck pendant to the arresting engine through the purchase cable. The cable is pulled out, causing the crosshead to move toward the fixed sheave assembly. The sheave damper installation is designed to reduce peak cable tension in the purchase cable by damping cable vibrations created by an aircraft engagement. A sheave damper installation is mounted below each port and starboard retractable sheave. As the cable is pulled out, the ram enters the cylinder, displacing hydraulic fluid from the cylinder through the constant runout valve to the accumulator for storage and use in retracting the engine to battery position. The constant runout valve is a unit of cams and levers, which meters fluid from the engine cylinder to the accumulator in such a manner that it automatically compensates for the aircraft's engaging velocity, stopping the aircraft as the valve slowly closes. Therefore, only the aircraft's weight must be known to set the control valve for a successful arrestment in a fixed

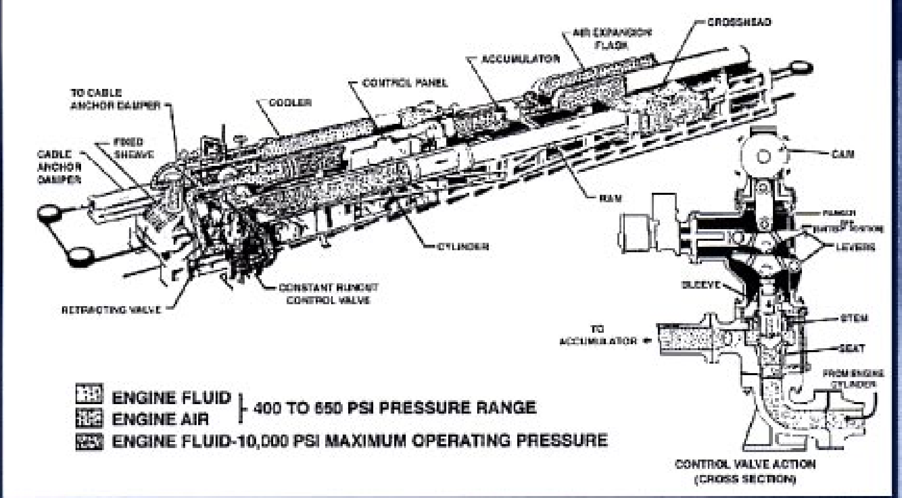


Figure 3

runout distance.

Figure 3 illustrates the typical hydraulic fluid flow during an arrestment.

After an arrestment, the retract valve assembly is used to return displaced engine cylinder fluid from the engine accumulator to the engine cylinder. The opening of the retracting valve is controlled at the flight deck by the retract lever. Accumulator pressure acting on the lower portion of the plunger holds the retracting valve in the closed position. During arrestment, engine cylinder pressure buildup acting on the lower portion of the retract valve stem ensures that the valve remains closed. To prevent excess fluid temperature, the hydraulic fluid passes through a cooler during retraction. An operator pulling the deck edge retracting valve lever opens the valve. Below deck, operators prepare the arresting gear for operation. Tethered via a sound-powered phone system, the operator receives instructions from above ground while watching the activity on a video monitor. As the aircraft approaches, operators shout instructions to one another that echo throughout the chamber. When the gear is set into action, the arresting gear traps the aircraft and a successful event is completed.

Since its inauguration in 1954, the TC-7 steam catapult and arresting gear facility has contributed to the success of fleet operations by testing and evaluating aircraft suitability for carrier operations. The continued operations of this unique test and evaluation facility ensure a safer and more productive future for Naval Aviation.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For further information, contact:

TC-7 Steam Catapult and
MK-7 Arresting Gear Test Site
Ship Suitability
and Landing Systems Department
Naval Strike Aircraft Test Squadron
Naval Air Warfare Center Aircraft Division
Patuxent River, Maryland 20670-5304
(301) 342-4441 or DSN 342-4441

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